USE OF SOYBEAN MEAL IN PLASTICS

Leonard L. McKinney
U. S. Regional Soybean Industrial Products Laboratory 1/
Urbana, Illinois

Because of the present emergency in which plastics are being used to replace metals, there is a severe shortage of plastic molding powders. The most common thermosetting molding powder is the phenolic type. One hundred fifty to two hundred million pounds of this type of molding material was produced in 1941. It is usually produced by condensing phenol and formaldehyde to form a fusible resin and subsequently compounding the resin with an equal part of wood flour, along with catalysts, lubricants, and coloring materials.

It has long been known that phenols and phenolic resins are compatible with soybean protein and soybean meal. Advantage has been taken of this fact to utilize the adhesive properties of soybean meal for supplementing those of phenolic resins in the phenolic resin-wood flour type of plastic. This development enables manufacturers to conserve the more expensive phenolic resin by replacing part of it with soybean meal.

The greatest problem involved in producing a plastic containing soybean meal is attainment of water resistance. Since soybean meal is highly water absorbent, it tends to impart this property to plastics when used as an ingredient. Treatment with formaldehyde improves the water resistance of soybean meal, but at the same time it decreases plastic-flow characteristics.

Another problem is to avoid increase in curing time. Thermosetting materials are discharged from a hot die while, with thermoplastic materials, the die must be cooled in order to set the plastic. Soybean protein is thermoplastic, provided a plasticizer is used. Phenolic resins in the early stage act as plasticizers for soybean meal. When the resin polymerizes to the insoluble, infusible state it no longer plasticizes the protein material and plastic flow stops. As a result the whole mixture sets up giving a thermosetting plastic which may be removed from the hot die.

Preparation of Meal

Oil-free soybean meal is not suitable for use in plastics without

1/ A cooperative organization participated in by the Bureaus of Agricultural Chemistry and Engineering and Plant Industry of the U. S. Department of Agriculture, and the Agricultural Experiment Stations of the North Central States of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

some modification. Soybean meal contains about 10 percent soluble sugars as well as other soluble materials which decrease water resistance. Thus if the untreated meal is used, blistering is likely to result probably due to decomposition of sugars. If meal is used, it must be washed free of soluble materials. This washing must be carried out with water adjusted to the isoelectric point of the protein, pH 4.1-4.3, in order to prevent leaching out some of the protein. After washing out the soluble sugars the meal must be given a heat treatment in order to denature or insolubilize the protein. This denaturation is carried out in the laboratory by raising the moisture content of the meal to about 20 percent and heating under pressure at a temperature of 225° to 250°F. for 2 or 3 hours. If the pressure is released suddenly, most of the water escapes as vapor and a dry product is obtained which is suitable for use in plastics. Somewhat the same results may be obtained by drying the wet leached meal at moderately high temperatures.

When protein is extracted from soybean meal a residue is left which is free of water-soluble sugars but may contain from 40 to 60 percent protein. If this material is heat-denatured, it makes an excellent material for use in phenolic plastics.

Preparation of Molding Powder

The following formula is typical of methods used for preparing molding powders in the laboratory:

94 parts phenol (1 mole ratio)
56 parts leached soybean meal, heat-treated
5 parts hydrated lime
Mix well and allow phenol to soak into meal.
Add 122 parts 37-percent formaldehyde solution (1.5 moles).
Heat in closed, steam-jacketed mixer for 15 minutes with steam pressure of 20 pounds per square inch.
Heat 1 hour with jacket temperature of 190° to 210°F.
Add 112 parts wood flour,
1 part calcium stearate,
1 part stearic acid,
11.66 parts hexamethylenetetramine (equivalent to 0.5 mole of formaldehyde).
Mix well and dry in air or vacuum at room temperature to a moisture content of less than 5 percent
Work on hot calender rolls or in Banbury mixer for 1 to 3 minutes. Grind to approximately 16 mesh to obtain molding powder.

The resin-forming reaction may be carried out in an autoclave or any steam-jacketed mixer which can be closed to prevent the escape of formaldehyde during the reaction. Drying may be accomplished by exhausting the air from the mixer or by spreading the material out for air drying.

A number of modifications may be made in the formula given above in order to modify properties of the molding powder or of the finished plastic. For example, hydrated lime may be replaced by barium hydroxide, calcium oxide, barium oxide, or ammonia. Hexamethylenetetramine may be replaced by paraformaldehyde, and part of the phenol may be replaced by cresols. Part of the wood flour may be replaced by asbestos fiber in order to give a faster-curing molding powder or a finished plastic with increased heat resistance.

From the proportions of phenol and formaldehyde specified in the formula, approximately 112 parts of phenolic resin will be produced. Half as much soybean meal (56 parts) and 112 parts of wood flour are specified. Therefore, the molding powder will have a composition of approximately 40 percent phenolic resin, 20 percent soybean meal, and 40 percent wood flour. The properties of such a plastic compare favorably with those of a phenolic plastic containing 50 percent phenolic resin and 50 percent wood flour and offers a saving of 10 percent in resin content. The amount of soybean meal in the molding powder may be increased to 30 percent with proportionate decrease in phenolic resin. However, an increase in meal content gives a plastic of increased water absorption and lower flexural and impact strengths. The molding powder made with higher meal content usually requires longer curing time and more pressure for molding.

It should be noted that best results have been obtained by forming the resin in the presence of the soybean meal as described above. Success of this procedure may be accounted for by assuming that the protein reacts with the resin in some manner and forms a perfectly homogeneous mass.

The conventional method for preparing phenolic-type molding powders involves making a fusible resin and grinding it with wood flour, catalysts, pigments, and lubricants in a ball mill. The powdered mixture is then compounded on hot calender rolls to obtain uniformity, and is again pulverized after cooling. The following formula is an example of this method in which 10 percent treated soybean meal is used.

40	percent	two-stage phenolic resin
5	"	hexamethylenetetramine
40	"	wood flour
10	"	treated meal
2	"	hydrated lime
1.25	"	stearic acid
1.75	"	nigrosine dye
100 percent		

Ball mill 24 hours.
Roll for 3 minutes with cold roll at 120°F. and hot roll at 205°F.

This material gave flow and strength properties comparable with molding powder made with 50 percent resin and 45 percent wood flour used as in the formula given above.

A large number of molding powders have been made in the laboratory in which the resin, wood flour, and meal contents were varied. It was concluded that a leached, denatured soybean meal can be used to replace as much as 5 or 10 percent of the more expensive resin without altering appreciably the curing time and strength properties of the final plastic. Since the meal is only about 50 percent protein, the remaining 50 percent being inert, nonplastic material, 10 percent meal must be used to replace 5 percent resin and 5 percent wood flour.

When soybean meal is used to replace wood flour, a strikingly large increase is noted in the plastic flow of the molding powder. In other words, a very free-flowing molding powder may be produced by using 50 percent resin, 40 percent wood flour, and 10 percent treated meal or protein residue. Such free-flowing molding powders are usually made by using 60 percent resin and 40 percent wood flour.

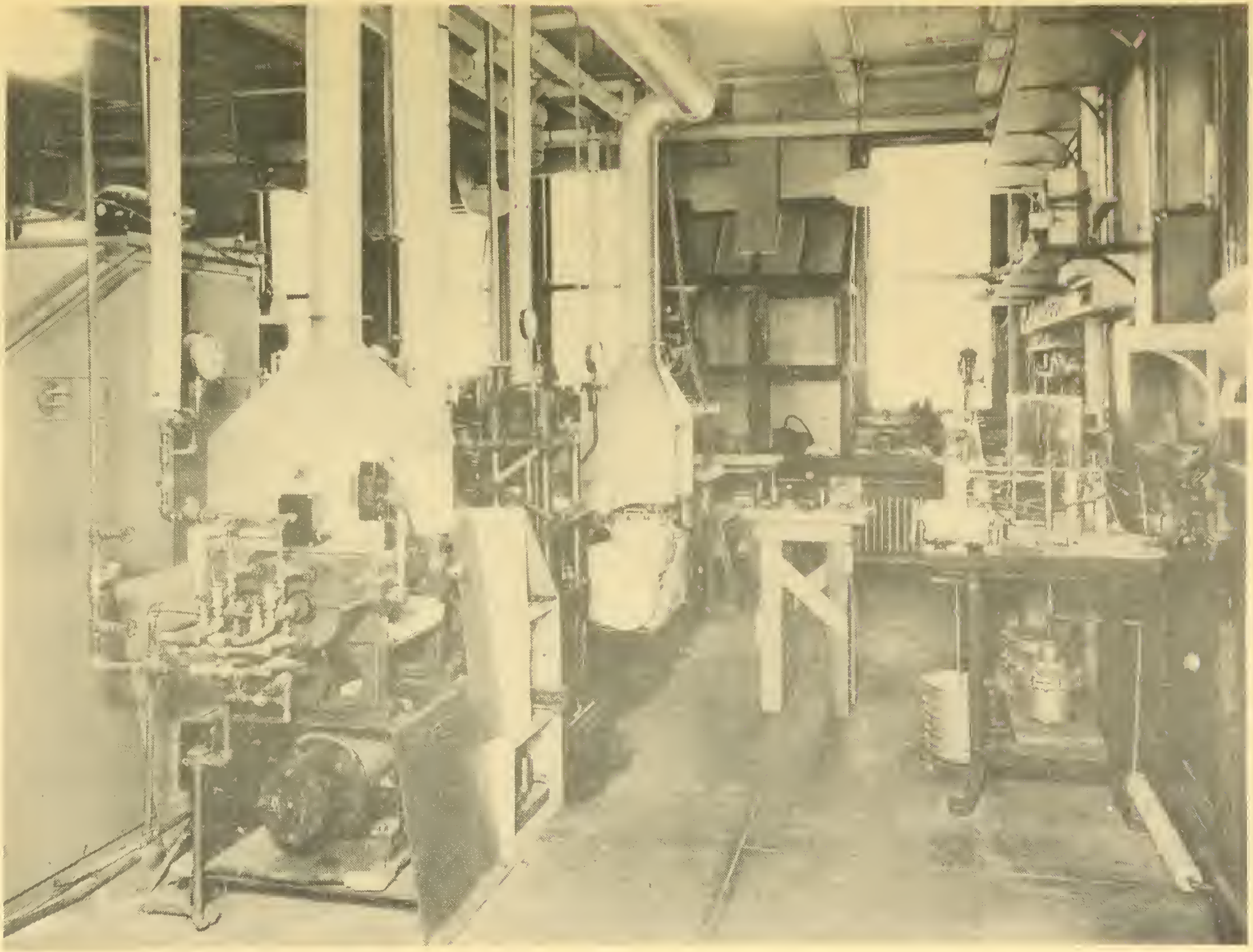
Colored Plastics

Both phenolic resin and wood flour are difficult to dye, and colors are therefore usually obtained by using pigments. Soybean meal offers a protein base for dyeing and tests show that phenolic plastics containing it are more stable to light than are phenolic plastics made without soybean meal when both kinds are colored with organic dye. Color may be obtained as follows:

Black - 2 percent nigrosine dye.
Brown - 2 percent burnt unber and 1 percent brown dye.
Red - 2 percent white clay and 2 percent Phenoform Red (General Dyestuff Corporation).
Blue - 2 percent white clay and 1 percent Duratint Blue 1001 (Federal Color Laboratories).
Green - 2 percent white clay and 2 percent green dye, A6318 (Kohnstamm).

Summary

It is possible to use 20 percent of treated soybean meal with 40 percent of phenol-formaldehyde resin and 40 percent of wood flour without decreasing the quality of the plastic or adding undesirable properties to the molding powder, in comparison with a 50:50 mixture of resin and wood flour. Dyeing properties are definitely improved by the use of protein material from soybeans. Moreover, the use of the protein material makes it possible to decrease the phenolic resin content because of the increased flow obtained with the soybean protein. Research is being continued in the U. S. Regional Soybean Industrial Products Laboratory with the idea of using a larger percentage of soybean-meal products in admixture with phenolic resins and obtaining a plastic which is not inferior to those now on the market.



Beginning at left (clockwise around room): 1. Compounding rolls.
2. Hydraulic press. 3. Mixer. 4. Plastics flow tester.